The influence of charge effects on the DC breakdown properties of HID lamps

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ABSTRACT

This paper describes DC breakdown voltage measurements on a metal halide lamp. The lamp (with short-circuited electrodes) is temporarily elevated to a high potential with respect to ground in between two consecutive experiments. This bias voltage has an influence on the statistical spread and the minimum breakdown voltage, caused by charges deposited on the arc tube wall.

INTRODUCTION

The ignition of high intensity discharge (HID) lamps requires high voltages (often in the kV range), especially when restarting warm lamps. Reducing these ignition voltages is of great interest and widely investigated [1]. Most of this research focuses on pulse-like voltage waveforms of only a few ns or µs long [1-3]. Other research is based on longer-duration AC and DC waveforms, which lead to different breakdown properties and other effects [3]. The breakdown experiments discussed in this paper make use of the test setup described in [4] to produce slowly rising DC voltages, i.e. DC ramps or pulses with a certain ramp rate and polarity. As Fig. 1 shows, breakdown occurs at a certain point in time (t_{BD}). The breakdown voltage V_{BD} is defined as the DC voltage across the lamp just before breakdown takes place, and is statistically distributed with a typical spread of several tens or hundreds of volts. Therefore, 75 samples for V_{BD} are collected in each measurement series, with an interval of Ts = 10 s. As Fig. 1 shows, during the breakdown experiments, one electrode of the lamp is connected to ground, while the other is connected to the DC voltage pulse v(t) with a positive or negative polarity. In between the samples, the entire lamp is elevated to a high common-mode potential with respect to earth: the bias voltage v(t) = V_{BIAS}. Both electrodes are short-circuited during this phase, breakdown does not occur. V_{BIAS} is removed 500 ms before the next sample begins.

MEASUREMENT RESULTS AND DISCUSSION

The presented experiments are performed on a Philips MHN-TD 70 W metal halide lamp, with a ramp rate of 600 V/s, and a variable bias voltage V_{BIAS}. Fig. 2 shows the measured V_{BD} distributions as a function of V_{BIAS} (positive and negative). Each distribution contains 75 measurement results. The boxplots represent the interquartile range (IQR) and the 5% and 95% quantiles (thin line). Clearly, the

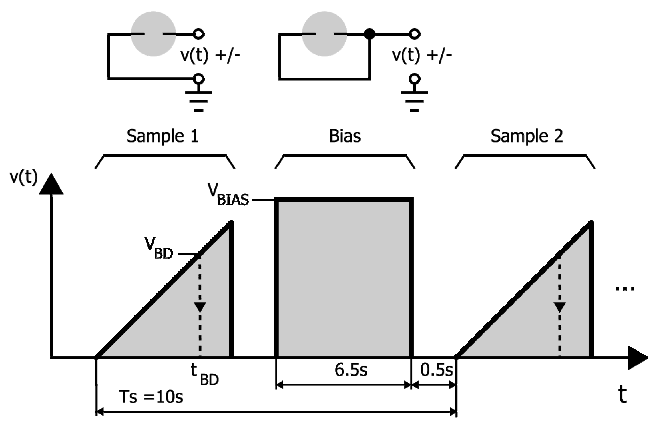

Fig. 1: Description of the breakdown experiments.

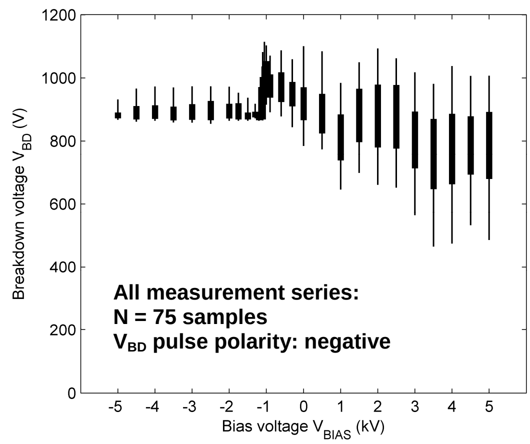

Fig. 2: Distribution of the breakdown voltage as a function of bias voltage.

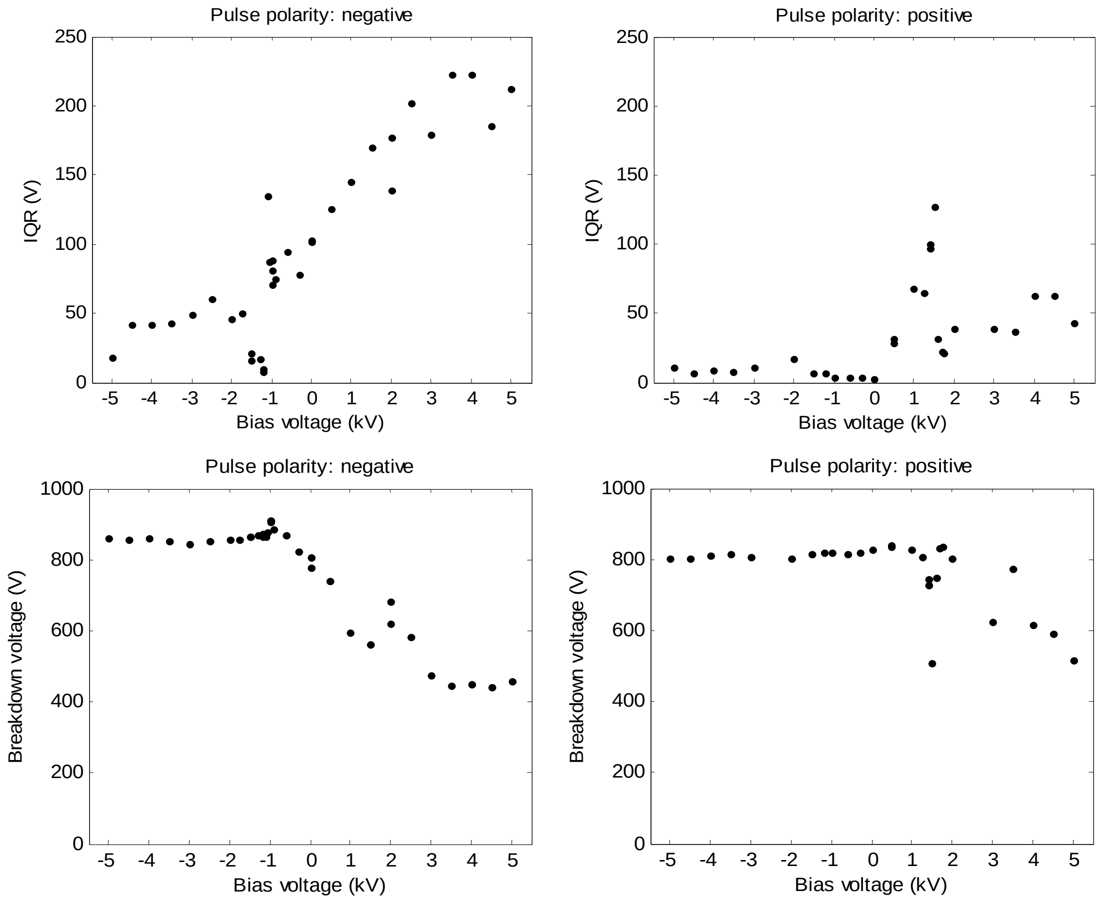

Fig. 3: Interquartile range (IQR) and minimum breakdown voltage as a function of V_{BIAS}.

polarity and the magnitude of V_{BIAS} have a strong influence on the range and the spread (IQR) of the distributions. Fig. 3 shows the IQR and the minimum breakdown voltage as a function of V_{BIAS}, for both negative (left) and positive (right) pulse polarities. Generally, a higher or more positive bias voltage leads to a higher IQR, and a lower minimum breakdown voltage. For both pulse polarities, a negative bias voltage results in a low and constant IQR, and a high and constant minimum V_{BD}. Discontinuities appear in the IQR when V_{BIAS} is around +1 kV and –1 kV. The minimum breakdown voltage then starts decreasing. It is believed that charge carriers are deposited on the arc tube wall during the bias phase, and later influence the electric field at the cathode during the measurement phase. A positive charge ($V_{BIAS} > 0$) enhances the field at the cathode, leading to a higher spread and a reduced minimum breakdown voltage. The effects are less pronounced for positive pulse voltages (the right figures), since the cathode is then grounded instead of connected to v(t) (increasing magnitude).

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